MULTIFUNCTIONAL COMPOSITES FOR VEHICLES

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Project ID: mat214

OVERVIEW

Timeline
- Project Start: June 29, 2020
- Project End: June 28, 2021
- Percent Complete: 90%

Budget
- Total Project funding: $200,000

Partners
- Toyota
- TPI Composites
- Project Lead: Trimer Technologies, LLC

Barriers and Technical Targets
- Composite exhibit poor electrical conductivity which is required for EMI shielding of electrical components and the dissipation of static electricity
- Quality control is more difficult than with metals and requires the development of non-destructive evaluation (NDE) techniques to ensure design and safety specifications are met
- Composite materials have greatly reduced thermal conductivity which can lead to increased stress in bonded joints as well as poor heat removal from components under the hood

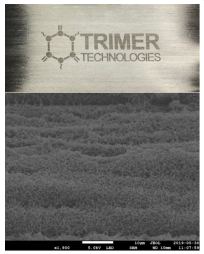
RELEVANCE

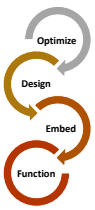
- Vehicle Technologies Office targeting a 25% glider weight reduction at less than $5/lb-saved by 2030
- DOE projects use of lightweight components and high-efficiency engines in only one-quarter of the U.S. fleet could save more than 5 billion gallons of fuel annually by 2030.
- This translates to a reduction of ~100 billion pounds of CO2 emissions annually and would further contribute to reducing N2O emissions.
- Composite usage in automotive applications is growing at a CAGR of 7.6% reaching $26 billion in 2025

Opportunity
- Carbon fiber composites provide 50-70% weight savings over steel
- Embedded sensors, electrical interconnects and EMI shielding as well as improved thermal conductivity will provide a step-change in vehicle energy efficiency, particularly for electric and autonomous vehicles

APPROACH

- The objective of the proposed SBIR program is to demonstrate the manufacture of multifunctional composites using graphene and its application for embedded sensing, thermal conductivity and EMI shielding
- Trimer has demonstrated that graphene can lead to both strength enhancement and embedded functionality
- The approach utilized can enable the patterning of the graphene to form functional electronic devices such as capacitors, resistors and inductors allowing passive circuit design
- Embedded functionality could lead to a step change in in vehicle energy efficiency, particularly for electric and autonomous vehicles





Graphene Process Optimization
- Optimize the graphene array length and density to maximize electrical conductivity and piezoresistivity.
- Evaluate the effect of processing parameters on the graphene structure.

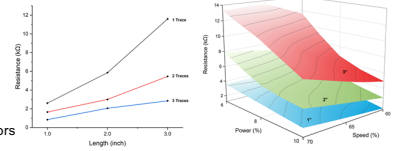
Composite Fabrication and Testing
- Transfer method development for Thermoplastic and Thermoset Prepreg processing.
- Manufacture composite panels using compression molding.

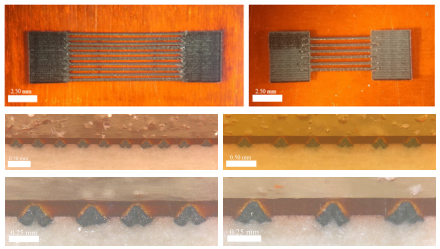
Development of Multifunctional Composites with Embedded Strain Sensing
- Measure electrical conductivity of graphene composites to determine feasibility of integrated multifunctionality.
- Characterize the strain sensing response of the LIG composites and determine the device sensitivity.
- Demonstrate the use of the LIG material for embedded damage detection and predictive failure.

Development of Multifunctional Composites with EMI Shielding
- Evaluate the LIG reinforcement for embedded EMI shielding.
- Optimize the LIG treatment to maximize the EMI shielding effectiveness.

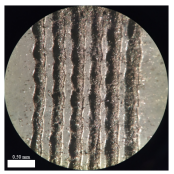
TECHNICAL ACCOMPLISHMENTS

Graphene Process Optimization
- Worked to control the graphene array length and density tailor electrical conductivity and piezoresistivity
- Increasing piezoresistivity found with increasing resistance
- Process allows for the design of sensors for various multifunctional behaviors

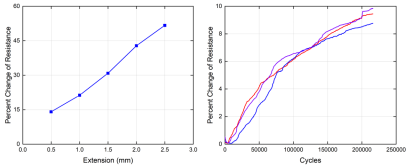




Strain Sensor Design
- Developed several designed for piezoresistive strain sensing
- Utilized both linear and serpentine patterns to tailor resistance

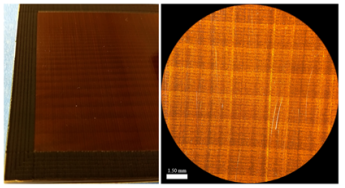


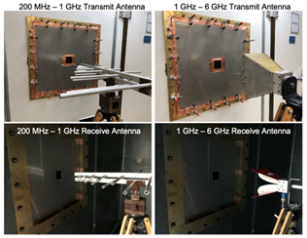
Flexural Response
- Characterized the sensor response to dynamic and static loading in tension and flexure.
- Demonstrated that the resistance change is linear with strain
- Have demonstrated that the resistance changes progressively during fatigue providing a mechanism to predict failure

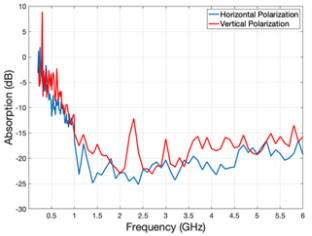


TECHNICAL ACCOMPLISHMENTS

EMI Shielding
- Trimer worked with Rhein Tech Laboratories to perform EMI shielding effectiveness testing to IEEE 299.1-2013
- Frequency Range: 200 MHz – 6 GHz
- Multifunctional graphene shielding effectiveness measured to average 21.2 dB across the spectrum
- Greater SE than Carbon Nanotubes while being cheaper/easier to produce

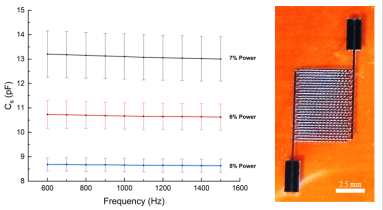


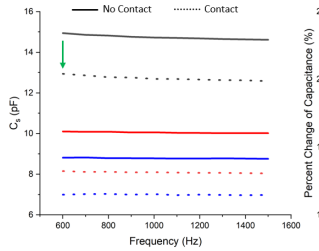


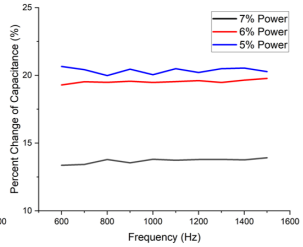


TECHNICAL ACCOMPLISHMENTS

Capacitive Based Touch Sensing
- Through discussion with industry partners, touch sensors embedded in the structure were determined to be a valuable multifunctional application
- Trimer developed capacitate based touch sensors that could be used to measure contact or strain
- Capacitance change due to contact with a fingertip
- Can function as a passive button integrated into the composite surface to replace the dummy panels used options not incorporated into the vehicle

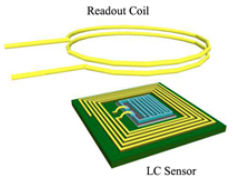






FUTURE RESEARCH

- Trimer will develop passive wireless sensors using an LC circuit design where a readout coil is magnetically coupled with the sensor, and the resonant frequency of the sensor is detected by monitoring the impedance of the readout coil
- Strain sensing will be accomplished through the piezoresistivity of the graphene material while touch sensing will be performed using capacitive coupling
- Proposed wireless sensing approach will enable numerous sensors to be simultaneously monitored without requiring power to each device
- Trimer will develop machine learning algorithms to provide structural prognostics



SUMMARY

- This work has shown that the graphene treatment can provide the ultimate multifunctional solution by embedding tailored sensors into structural composites providing both component functionality while simultaneously increasing strength
- Graphene can be directly produced on the surface of the thermoplastic composites therefore providing functionality with added cost of raw materials thus increasing the value of components being manufactured
- Sensors can be manufactured to provide measurement of strain as well as pressure, therefore enabling the application of the technology to tracking structural health and make predictions on a components remaining life
- The process proposed by Trimer Technologies is advantageous to other multifunctional methodologies because the treatment is directly applied to the prepreg, therefore, making it compatible with current manufacturing processes and is low-cost since the process can be applied to commercial thermoplastic films or currently used thermoset materials.
- This research directly addresses the goals set by U.S. DRIVES's Materials Technical Team through the development and characterization of a new low-cost technique to create multifunctional composites with embedded sensors, electrical interconnects and EMI shielding and will provide a step-change in vehicle energy efficiency, particularly for electric and autonomous vehicles.